Spreadsheet Formulas for the Wilcoxon Rank Sum Test and Power Calculation

Wilcoxon Rank Sum Test, per NUREG-1505

LBGR 2.6 *(For this calculation, LBGR = 3w for Building 2078 Background)*
(Reference Dataset - Building 2078 Alpha Hand-held)

DATA	AREA	ADJUSTED DATA	RANKS	SURVEY AREA RANKS
2	R	2	31	0
0	R	0	14	0
3	R	3	37	0
2	R	2	31	0
2	R	2	31	0
5	R	5	41	0
1	R	1	23	0
2	R	2	31	0
1	R	1	23	0
0	R	0	14	0
2	R	2	31	0
3	R	3	37	0
3	R	3	37	0
3	R	3	37	0
4	R	4	40	0
2	R	2	31	0
1	R	1	23	0
1	R	1	23	0
0	R	0	14	0
0	R	0	14	0
1	R	1	23	0
1	R	1	23	0
3	R	3	37	0
2	R	2	31	0
1	R	1	23	0
0	R	0	14	0
0	R	0	14	0
0	R	0	14	0
0	R	0	14	0
1	R	1	23	0
1	R	1	23	0
0	R	0	14	0
2	S	-0.6	8	8
0	S	-2.6	2.5	2.5
2	S	-0.6	8	8
0	S	-2.6	2.5	2.5
0	S	-2.6	2.5	2.5
2	S	-0.6	8	8
1	S	-1.6	5.5	5.5
1	S	-1.6	5.5	5.5
0	S	-2.6	2.5	2.5
		Sum =	861	45

* This spreadsheet is originally designed to work with a set of twenty measurements, 10 from the survey unit (S) and 10 from the background reference area (R).
If a different number of measurements have been performed, it is necessary to modify the spreadsheet to account for the change in the number of measurements.

# of R:	32	*n*
# of S:	9	*m*
Avg Rank R:	26	
Avg Rank S:	5	

For *m* or *n* greater than 20, the critical value (k) can be calculated for Scenario B from

$$\frac{m(n+m+1)}{2} + z\sqrt{\frac{nm(n+m+1)}{12}}$$

z = 97.5% percentile of standard normal distribution = 1.960

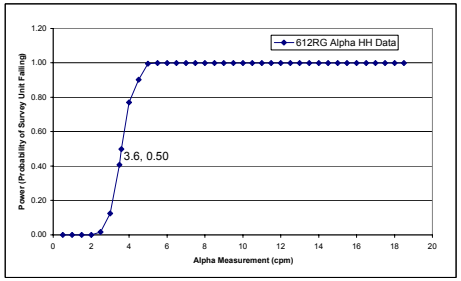
k = 251.2

Since the sum of survey unit ranks is less than the critical value, the null hypothesis that the difference between the survey unit median and the background median is less than the LBGR (i.e., the survey unit is indistinguishable from background) is accepted and the survey unit passes.*Scenario B*

Survey Unit Stats		
Count	9	*m*
SD	0.93	
Median	0.5	
Reference Stats		
Count	32	*n*
SD	1.32	
Median	1.0	
Critical Value	251.2	
Bkgd Median plus LBGR	3.6	

Retrospective Power Curve Calculatior *p1* and *p2* pull data from Table 10-3 shee
From Example in Section 10.5 of NUREG-1505

C Measurement	(C-LBGR)/SD	Rounded	p1	p2	E(Wmw)	Var(Wmw)	SD(Wmw)	z	Power
0.5	-1.592	-1.600	0.12895	0.046501	37.1376	402.2947	20.05728	8.405448	0.00
1	-1.213	-1.200	0.198072	0.085944	57.04474	624.2208	24.98441	5.951044	0.00
1.5	-0.8337	-0.800	0.262259	0.12892	75.53059	800.4985	28.29308	4.601743	0.00
2	-0.4547	-0.500	0.361837	0.206266	104.2091	999.5127	31.61507	3.211096	0.00
2.5	-0.0758	-0.100	0.471814	0.305606	135.8824	1099.613	33.16041	2.106296	0.02
3	0.3032	0.300	0.583998	0.421415	168.1914	1065.163	32.63683	1.150131	0.13
3.5	0.6821	0.700	0.689691	0.544073	198.631	908.6942	30.14456	0.235434	0.41
3.6	**0.7579**	**0.800**	**0.714196**	**0.574469**	**205.6884**	**856.2304**	**29.26141**	**0.001354**	**0.50**
4	1.0611	1.100	0.781662	0.662216	225.1187	683.4668	26.1432	-0.74171	0.77
4.5	1.4400	1.400	0.821015	0.716331	236.4523	565.7358	23.7852	-1.29174	0.90
5	1.8190	1.800	0.885334	0.810016	254.9762	353.6943	18.80676	-2.61864	1.00
5.5	2.1979	2.200	0.931218	0.881527	268.1908	196.2814	14.01005	-4.45842	1.00
6	2.5768	2.600	0.96145	0.931365	276.8976	97.10107	9.853987	-7.22241	1.00
6.5	2.9558	3.000	0.979848	0.963118	282.1962	43.03569	6.560159	-11.6564	1.00
7	3.3347	3.300	0.988174	0.977981	284.5941	21.85673	4.675118	-16.8693	1.00
7.5	3.7137	3.700	0.993336	0.98741	286.0808	10.49587	3.239734	-24.8023	1.00
8	4.0926	4.100	0.997661	0.995497	287.3264	2.771504	1.664784	-49.0144	1.00
8.5	4.4716	4.500	0.997661	0.995497	287.3264	2.771504	1.664784	-49.0144	1.00
9	4.8505	4.900	0.997661	0.995497	287.3264	2.771504	1.664784	-49.0144	1.00
9.5	5.2295	5.200	0.999796	0.999599	287.9412	0.144913	0.380674	-215.967	1.00
10	5.6084	5.600	0.999796	0.999599	287.9412	0.144913	0.380674	-215.967	1.00
10.5	5.9874	6.000	0.999989	0.999978	287.9968	0.003166	0.056271	-1462	1.00
11	6.3663	6.400	0.999989	0.999978	287.9968	0.003166	0.056271	-1462	1.00
11.5	6.7453	6.700	0.999989	0.999978	287.9968	0.003166	0.056271	-1462	1.00
12	7.1242	7.100	0.999989	0.999978	287.9968	0.003166	0.056271	-1462	1.00
12.5	7.5032	7.500	0.999989	0.999978	287.9968	0.003166	0.056271	-1462	1
13	7.8821	7.900	0.999989	0.999978	287.9968	0.003166	0.056271	-1462	1
13.5	8.2611	8.300	0.999989	0.999978	287.9968	0.003166	0.056271	-1462	1
14	8.6400	8.600	0.999989	0.999978	287.9968	0.003166	0.056271	-1462	1
14.5	9.0190	9.000	0.999989	0.999978	287.9968	0.003166	0.056271	-1462	1
15	9.3979	9.400	0.999989	0.999978	287.9968	0.003166	0.056271	-1462	1
15.5	9.7769	9.800	0.999989	0.999978	287.9968	0.003166	0.056271	-1462	1
16	10.1558	10.200	0.999989	0.999978	287.9968	0.003166	0.056271	-1462	1
16.5	10.5348	10.500	0.999989	0.999978	287.9968	0.003166	0.056271	-1462	1
17	10.9137	10.900	0.999989	0.999978	287.9968	0.003166	0.056271	-1462	1
17.5	11.2927	11.300	0.999989	0.999978	287.9968	0.003166	0.056271	-1462	1
18	11.6716	11.700	0.999989	0.999978	287.9968	0.003166	0.056271	-1462	1
18.5	12.0505	12.100	0.999989	0.999978	287.9968	0.003166	0.056271	-1462	1



Based on the number of measurements and the observed standard deviation, a survey unit with a median measurement equal to the background median plus the LBGR (3.6) will have a 0.50 probability that the survey unit will **correctly** fail (i.e., the null hypothesis that the difference between the survey unit median and the background median is less than the LBGR [i.e., the survey unit is indistinguishable from background] is rejected).

Spreadsheet Formulas for the Wilcoxon Rank Sum Test and Power Calculation

Wilcoxon Rank Sum Test, per NUREG-1505

LBGR 327.7 *(For this calculation, LBGR = 3w for Building 2078 Background)*
(Reference Dataset - Building 2078 Beta Hand-held)

DATA	AREA	ADJUSTED DATA	RANKS	SURVEY AREA RANKS
192	R	192	34	0
172	R	172	28	0
170	R	170	26.5	0
182	R	182	32	0
173	R	173	29.5	0
170	R	170	26.5	0
173	R	173	29.5	0
163	R	163	25	0
160	R	160	23.5	0
175	R	175	31	0
160	R	160	23.5	0
153	R	153	21	0
156	R	156	22	0
136	R	136	17	0
150	R	150	19.5	0
150	R	150	19.5	0
141	R	141	18	0
291	R	291	36	0
112	R	112	12	0
110	R	110	11	0
128	R	128	14	0
134	R	134	15.5	0
119	R	119	13	0
99	R	99	10	0
186	R	186	33	0
134	R	134	15.5	0
336	R	336	41	0
320	R	320	38	0
326	R	326	39	0
233	R	233	35	0
315	R	315	37	0
327	R	327	40	0
141	S	-186.7	7	7
151	S	-176.7	8	8
103	S	-224.7	2	2
126	S	-201.7	3	3
137	S	-190.7	6	6
131	S	-196.7	5	5
128	S	-199.7	4	4
157	S	-170.7	9	9
94	S	-233.7	1	1
		Sum =	861	45

	Survey Unit Stats	
Count	9	*m*
SD	20.57	
Median	129.5	
	Reference Stats	
Count	32	*n*
SD	70.50	
Median	166.5	
Critical Value	251.2	
Bkgd Median plus LBGR	494.2	

* This spreadsheet is originally designed to work with a set of twenty measurements, 10 from the survey unit (S) and 10 from the background reference area (R).
If a different number of measurements have been performed, it is necessary to modify the spreadsheet to account for the change in the number of measurements.

# of R:	32	*n*
# of S:	9	*m*
Avg Rank R:	26	
Avg Rank S:	5	

For *m* or *n* greater than 20, the critical value (k) can be calculated for Scenario B from

$$\frac{m(n+m+1)}{2} + z\sqrt{\frac{nm(n+m+1)}{12}}$$

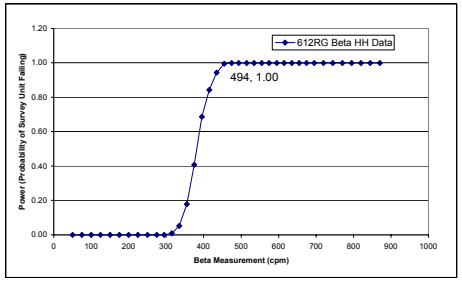
z = 97.5% percentile of standard normal distribution = 1.960

k = 251.2

Since the sum of survey unit ranks is less than the critical value, the null hypothesis that the difference between the survey unit median and the background median is less than the LBGR (i.e., the survey unit is indistinguishable from background) is accepted and the survey unit passes.*Scenario B*

Retrospective Power Curve Calculatior *p1* and *p2* pull data from Table 10-3 shee
From Example in Section 10.5 of NUREG-1505

C Measurement	(C-LBGR)/SD	Rounded	p1	p2	E(Wmw)	Var(Wmw)	SD(Wmw)	z	Power
50	-3.939	-3.900	0.002339	0.000174	0.673632	2.75912	1.66106	123.4479	0.00
75	-3.584	-3.600	0.002339	0.000174	0.673632	2.75912	1.66106	123.4479	0.00
100	-3.2296	-3.200	0.006664	0.000738	1.919232	10.49587	3.239734	62.90913	0.00
125	-2.8750	-2.900	0.016947	0.00269	4.880736	34.55429	5.878289	34.16765	0.00
150	-2.5204	-2.500	0.03855	0.008465	11.1024	97.10107	9.853987	19.75096	0.00
175	-2.1658	-2.200	0.03855	0.008465	11.1024	97.10107	9.853987	19.75096	0.00
200	-1.8112	-1.800	0.101546	0.033114	29.24525	308.6606	17.56874	10.04528	0.00
225	-1.4566	-1.500	0.144422	0.054656	41.59354	454.1445	21.31067	7.70199	0.00
250	-1.1021	-1.100	0.198072	0.085944	57.04474	624.2208	24.98441	5.951044	0.00
275	-0.7475	-0.700	0.310309	0.164691	89.36899	908.6942	30.14456	3.860036	0.00
295	-0.4638	-0.500	0.361837	0.206266	104.2091	999.5127	31.61507	3.211096	0.00
315	-0.1801	-0.200	0.443769	0.27893	127.8055	1086.566	32.9631	2.363934	0.01
335	0.1035	0.100	0.528186	0.361978	152.1176	1099.613	33.16041	1.616702	0.05
355	0.3872	0.400	0.611351	0.451875	176.0691	1035.929	32.18584	0.921492	0.18
375	0.6709	0.700	0.689691	0.544073	198.631	908.6942	30.14456	0.235434	0.41
395	0.9545	1.000	0.76025	0.633702	218.952	742.5542	27.24985	-0.48528	0.69
415	1.2382	1.200	0.801928	0.6898	230.9553	624.2208	24.98441	-1.00972	0.84
435	1.5219	1.500	0.838901	0.741698	241.6035	508.8096	22.55681	-1.59045	0.94
455	1.8055	1.800	0.885334	0.810016	254.9762	353.6943	18.80676	-2.61864	1.00
475	2.0892	2.100	0.92135	0.865767	265.3488	229.9262	15.16332	-3.93191	1.00
494	**2.3587**	**2.400**	**0.948062**	**0.908982**	**273.0419**	**140.0082**	**11.83251**	**-5.68889**	**1.00**
515	2.6566	2.700	0.967004	0.940817	278.4972	80.02904	8.945895	-8.13435	1.00
535	2.9402	2.900	0.976143	0.956616	281.1292	53.28119	7.299396	-10.3298	1.00
555	3.2239	3.200	0.985811	0.973725	283.9136	27.57876	5.251548	-14.8881	1.00
575	3.5076	3.500	0.991895	0.984758	285.6658	13.48952	3.672808	-21.7647	1.00
595	3.7912	3.800	0.993336	0.98741	286.0808	10.49587	3.239734	-24.8023	1.00
615	4.0749	4.100	0.997661	0.995497	287.3264	2.771504	1.664784	-49.0144	1.00
635	4.3586	4.400	0.997661	0.995497	287.3264	2.771504	1.664784	-49.0144	1.00
655	4.6422	4.600	0.997661	0.995497	287.3264	2.771504	1.664784	-49.0144	1.00
675	4.9259	4.900	0.997661	0.995497	287.3264	2.771504	1.664784	-49.0144	1.00
695	5.2096	5.200	0.999796	0.999599	287.9412	0.144913	0.380674	-215.967	1.00
720	5.5642	5.600	0.999796	0.999599	287.9412	0.144913	0.380674	-215.967	1.00
745	5.9187	5.900	0.999796	0.999599	287.9412	0.144913	0.380674	-215.967	1.00
770	6.2733	6.300	0.999989	0.999978	287.9968	0.003166	0.056271	-1462	1.00
795	6.6279	6.600	0.999989	0.999978	287.9968	0.003166	0.056271	-1462	1.00
820	6.9825	7.000	0.999989	0.999978	287.9968	0.003166	0.056271	-1462	1.00
845	7.3371	7.300	0.999989	0.999978	287.9968	0.003166	0.056271	-1462	1.00
870	7.6917	7.700	0.999989	0.999978	287.9968	0.003166	0.056271	-1462	1.00



Based on the number of measurements and the observed standard deviation, a survey unit with a median measurement equal to the background median plus the LBGR (494) will have a 1.0 probability that the survey unit will **correctly** fail (i.e., the null hypothesis that the difference between the survey unit median and the background median is less than the LBGR [i.e., the survey unit is indistinguishable from background] is rejected).

Quantile Test

per Section 7 of NUREG-1505		From Table A.7	
n (Survey)	9	*r*	6
m (Ref)	32	*k*	4
alpha/2	0.025	*alpha*	0.026

If *k* of the *r* largest ranks are from the survey unit, the null hypoth
(10,30) in Table A.7

Alpha Hand-held Ranks		Beta Hand-held Ranks	
Sorted Ranks	Location	Sorted Ranks	Location
2.5	S	1	S
2.5	S	2	S
2.5	S	3	S
2.5	S	4	S
5.5	S	5	S
5.5	S	6	S
8	S	7	S
8	S	8	S
8	S	9	S
14	R	10	R
14	R	11	R
14	R	12	R
14	R	13	R
14	R	14	R
14	R	15.5	R
14	R	15.5	R
14	R	17	R
14	R	18	R
23	R	19.5	R
23	R	19.5	R
23	R	21	R
23	R	22	R
23	R	23.5	R
23	R	23.5	R
23	R	25	R
23	R	26.5	R
23	R	26.5	R
31	R	28	R
31	R	29.5	R
31	R	29.5	R
31	R	31	R
31	R	32	R
31	R	33	R
31	R	34	R
37	R	35	R
37	R	36	R
37	R	37	R
37	R	38	R
37	R	39	R
40	R	40	R
41	R	41	R
0 of top 6 from S		**0 of top 6 from S**	

If the *r*-th largest measurement is among a group of tied (equal-in-value) measurements, increase *r* to include the tied measurements. Also increase *k* by the same amount (EPA 230-R-94-004).

r=7
k=5
0 of top 7 from S

hesis is rejected.

Reproduction of Table 10-3 from NUREG-1505

(C-LBGR)/SD	p1	p2
-6.0	0.00001	0
-5.0	0.000204	0.00001
-4.0	0.002339	0.000174
-3.5	0.006664	0.000738
-3.0	0.016947	0.00269
-2.5	0.03855	0.008465
-2.0	0.07865	0.023066
-1.9	0.089555	0.027714
-1.8	0.101546	0.033114
-1.7	0.114666	0.039348
-1.6	0.12895	0.046501
-1.5	0.144422	0.054656
-1.4	0.161099	0.063897
-1.3	0.178985	0.074301
-1.2	0.198072	0.085944
-1.1	0.218338	0.098892
-1.0	0.23975	0.113202
-0.9	0.262259	0.12892
-0.8	0.285804	0.146077
-0.7	0.310309	0.164691
-0.6	0.335687	0.18476
-0.5	0.361837	0.206266
-0.4	0.388649	0.229172
-0.3	0.416002	0.253419
-0.2	0.443769	0.27893
-0.1	0.471814	0.305606
0.0	0.5	0.333333
0.1	0.528186	0.361978
0.2	0.556231	0.391392
0.3	0.583998	0.421415
0.4	0.611351	0.451875
0.5	0.638163	0.482593
0.6	0.664313	0.513387
0.7	0.689691	0.544073
0.8	0.714196	0.574469
0.9	0.737741	0.604402
1.0	0.76025	0.633702
1.1	0.781662	0.662216
1.2	0.801928	0.6898
1.3	0.821015	0.716331
1.4	0.838901	0.741698
1.5	0.855578	0.765812
1.6	0.87105	0.788602
1.7	0.885334	0.810016
1.8	0.898454	0.830022
1.9	0.910445	0.848605
2.0	0.92135	0.865767
2.1	0.931218	0.881527
2.2	0.940103	0.895917
2.3	0.948062	0.908982
2.4	0.955157	0.920777
2.5	0.96145	0.931365
2.6	0.967004	0.940817
2.7	0.971881	0.949208
2.8	0.976143	0.956616
2.9	0.979848	0.963118
3.0	0.983053	0.968795
3.1	0.985811	0.973725
3.2	0.988174	0.977981
3.3	0.990188	0.981636
3.4	0.991895	0.984758
3.5	0.993336	0.98741
4.0	0.997661	0.995497
5.0	0.999796	0.999599
6.0	0.999989	0.999978